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## Paper Session II-A - Space Station Payload Adaptation System

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ABSTRACT

**Space Station Payload Adaptation System**

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The internal, pressurized payloads used on early flight of the Space Station will consist of many payloads and on-going investigations carried over from the Shuttle. Therefore, the Space Station will require a small payload carrier that can adapt Shuttle payloads to the Space Station and also offer these transitional payloads the full advantages of Space Station capabilities such as longer microgravity periods, increased crew availability and increased resources such as power, data and heat rejection capability.

An end-to-end systems analysis of payload integration activities dictates the need for improved containers to fully exploit Space Station resources, improved operation efficiency and increase design flexibility. In response to this need, improved payload containers as well as a structure to adapt these and existing payload containers to the Space Station rack system have been designed.

The Space Station Payload Adaptation System evolved from design efforts aimed at accommodating a wide spectrum of materials processing payloads which require a broad range of resources, produce a large number of samples and require on-orbit servicing. This system can also provide the same capabilities to a broad cross-section of payloads originally designed to Shuttle interfaces.

A Space Station facility concept will be presented that will fully exploit the advantages offered by Space Station operations. This rack mounting concept used in conjunction with improved experiment containers will allow experiment and sample change-out, payload reconfiguration, and maintenance/refurbishment activities that are consistent with NASA on-orbit safety requirements.

## Introduction

Space Shuttle and Spacelab Materials Processing in Space (MPS) scientific investigations, which began in the early 1980's, have generated and will continue to generate a considerable number of payloads. In fact, the average non-DoD Shuttle mission carries about 2.3 MPS payloads. Moreover, there is and will continue to be a large group of investigators and design engineers who are familiar with Shuttle and Spacelab interfaces. When the Space Station becomes operational there will be a large inventory of payloads available that were originally designed to Shuttle and Spacelab interfaces.

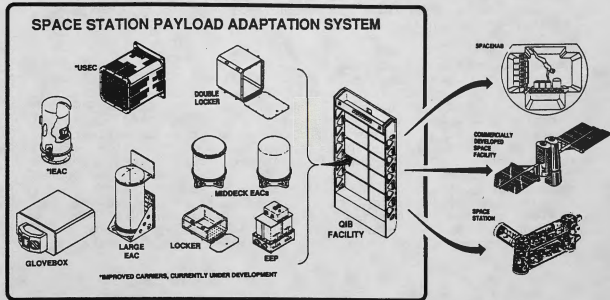
A more streamlined and cost effective approach for payload integration and operations must be developed to cope with the increase in payload activity posed by Space Station operations. Whereas, we now have seven day Shuttle and/or Spacelab missions at the rate of six or so a year, Space Station will be about a ten-fold increase in time in orbit. Moreover, Space Station can accommodate at least an order of magnitude increase in numbers of payloads in orbit and perhaps three orders of magnitude increase in experiment runs per year. Therefore, operational efficiency must increase to fully exploit the benefits of Space Station.

Many of the Space Shuttle and Spacelab payloads will be key steps in ongoing investigations that need to be completed on Space Station. Also, many will benefit from the longer duration and additional resources that Space Station will provide. This specific class of investigations, which are characterized by small size, moderate resource requirements and need for rapid deployment and reflight, have been referred to using the phrase "Quick is Beautiful"<sup>1</sup> (QIB).

These factors added to the growing backlog of flight requirements dictate a need for an adapter to provide a transition for these Shuttle and Spacelab payloads to the Space Station. Such an adapter will save time and money. It will be far more cost effective to adapt the Space Station to these existing payload interfaces rather than redesign all the existing payloads. Moreover, it will allow scientists and engineers to concentrate their limited resources on their investigations rather than devoting time and energy to adapting their payload to new interfaces.

The Space Station Payload Adaptation System (SSPAS) presented in this paper is composed of: 1) A carrier for pressurized payloads (the QIB Facility), and 2) two payload containers, the Universal Small Experiment Container (USEC) and Improved Experiment Apparatus Container (IEAC). To accommodate existing and envisioned payloads we have taken the systems approach (see figure 1), in order to minimize payload design and operational complexity.

Such an adaptation system can supply levels of containment, augment safety, and provide for convenient servicing and access. These provisions are vital to successful and cost effective Space Station operation, since it takes some of the burden off the investigator, such as meeting NASA's design standards, integration procedures, and most important of all, safety requirements.



**Figure 1. Space Station Payload Adaptation System**

The standardization of interfaces increases access to space and is advantageous from both a cost and schedule standpoint. The most logical location for the standardization of interfaces is the junction between the experiment payload and its rack support structure. By standardizing this interface, opportunities for flight will be increased because hardware that has been designed to this standard interface will be compatible with a large number of carriers. Integration time could also be reduced, especially on reflight of hardware, through the reduction in the number of interfaces that must be verified each time a new carrier is flown. Although the burden of safety and interface verification will never be completely eliminated, a standard interface for all rack mounted structures would minimize the lengthy process of payload element design, verification, safety planning, testing, and documentation.

Once an experiment has been qualified for flight to a standard interface, no modification of the hardware would be required if the hardware were to be manifested for flight in an alternate location. As an example, experiments that are designed to fly in the USEC as depicted in figure 1, could be accommodated in the middeck, in a rack in Spacelab, on the wall of SPACEHAB, in a rack in SPACEHAB, or in the QIB facility in the Space Station US Laboratory. The elimination of costly and time consuming redesign of experiment hardware to meet different interfaces will simplify the experimentation process and allow principal investigators to focus on the scientific phenomena of microgravity.

This is an example of end-to-end systems design approach employed by the Space Station Payload Adaptation System (SSPAS).

employed by the Space Station Payload Adaptation System (SSPAS). An approach that provides for operational efficiency, enhanced safety, and reliability.

#### SSPAS Subsystems Description

The "Quick is Beautiful" (QIB) facility, also depicted in figure 1, is a multipurpose, small payload carrier being designed and developed for NASA by Wyle Laboratories. This facility will provide easy access to space for small to medium sized microgravity research projects, allowing proof-of-concept type investigations. Both the Orbiter and the Space Station can provide a wide variety of resources to an experimenter. Examples of these resources are electrical power, air and water cooling, data, command and control, vacuum/vent, source gases, ultra pure water and others. Access to these resources is accomplished through an interface between the payload and the Orbiter or, in the case of Spacelab and Space Station an interface between the payload and a rack. The QIB carrier derives its utility through standardization of interfaces.

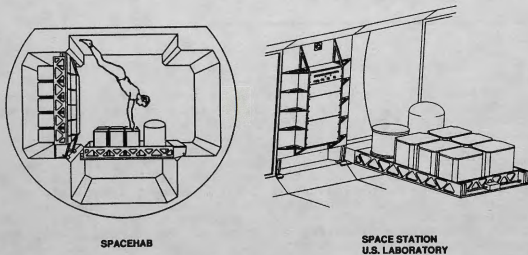
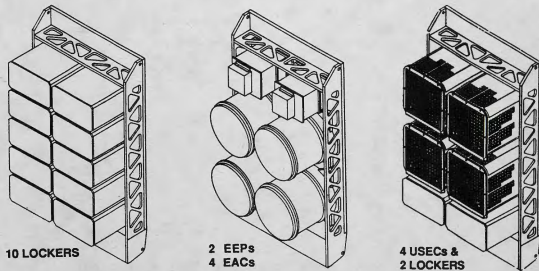


Figure 2. SSPAS Module Configuration

The overall physical envelope has been selected to ensure that upward compatibility is being maintained with the Space Station rack envelope (currently 41.5" wide X 74.5" high). The development of the facility is being targeted for flight aboard SPACEHAB (in a test bed mode), the Commercially Developed Space Facility and, eventual transition to the Space Station. The QIB, mounted in the SPACEHAB and Space Station US Laboratory module, is illustrated in figure 2. The QIB will be capable of accommodating small payload carriers designed for the middeck interface. Potential carriers are middeck lockers, Experiment Apparatus Containers (EACs), double

lockers, middeck electronics modules, gloveboxes, and experiment unique hardware as well as the USEC and IEAC. Figure 3 depicts several of the possible configurations of the QIB facility.



**Figure 3. SSPAS Potential Configurations**

The QIB structure is comparable to a vertical pallet type structure. Payloads will be mounted to the rear of the structure using standard middeck experiment mounting plates. As illustrated in figure 2, the QIB is easily rotated into a horizontal position for sample exchange, experiment reconfiguration, payload change-out, adjustments, refurbishments and repairs. Power distribution hardware and control instrumentation are mounted on the front of the structure for easy access by payload specialists.

The design objectives for the QIB are to provide flexible accommodations for all small experiment carriers, provide a full range of resources available to experimenters (power, data, venting, cooling), and allow for rapid integration prior to flight. An additional objective of the QIB is to serve as a Space Station engineering and operational test bed facility to: 1) demonstrate on-orbit reconfiguration procedures for payloads, 2) perform operations tests of crew interaction procedures and human factors, 3) test and verify safety procedures for change-out of samples and experiments, and 4) demonstrate reconfiguration of resource connectors (power data, fluid, vacuum), fasteners, wires, and cables. These precursor tests of essential Space Station operations will contribute to the development of technology critical to the optimum utilization of the Space Station in it's long duration operational mode.

The module will provide a complete set of resources to the double rack locations including power, thermal, data, and access to a vacuum/vent valve. When the QIB is used in the SPACEHAB module, the primary power source will be 28 VDC with the possibility of a limited amount of AC power. Cooling air will be supplied to the

top of the rack and withdrawn at the bottom. For additional heat rejection, rack mounted payloads can interface with a SPACEHAB experiment heat exchanger for water cooling.

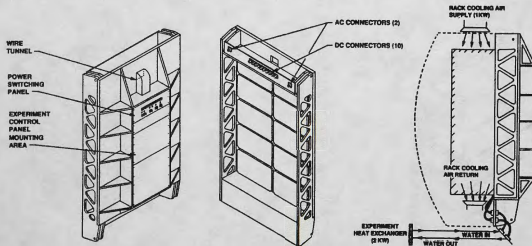


Figure 4. Power Distribution and Heat Rejection

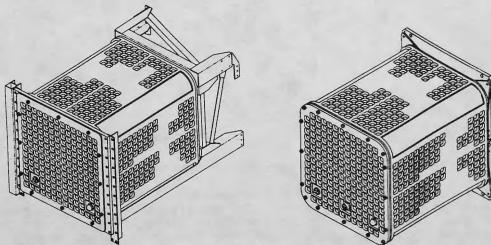
The QIB will provide both AC and DC power connections. Approximately 1 kW of 28 volt DC power will be provided through 10 DC connectors located on the payload side of the QIB. As an optional service, 115 volt AC power will also be provided. The power switching panel for activation of experiments is located on the front of the QIB. Payload heat rejection will be provided by an avionics air loop. This loop will supply cooling air at the top of the QIB rack location and draw the cooling air out at a return duct located below the rack. The air loop will be capable of rejecting approximately 1 kW of heat from the payloads mounted on the QIB. Additional heat rejection capability is provided by a water loop connection with an experiment heat exchanger located outside of the module. This water loop will provide an additional 2 kW of heat rejection capability. Power and heat rejection design concepts are depicted in figure 4.

Another component of the Space Station Adaptation System is the USEC, depicted in figure 5. The USEC design and development effort currently under way at Wyle Laboratories addresses several issues currently confronting investigators wishing to fly experiments aboard the Space Transportation System (STS). These issues include incompatibility of various experiment carriers, safe processing and handling of toxic materials and procedures for on-orbit change-out of samples and materials.

Currently there are two options available for internal, pressurized experiment accommodations aboard the Shuttle. Lockers, Experiment Apparatus Containers (EAC) and the Middeck Accommodations Rack are available in the middeck. Rack and floor mounted accommodations are available in the Spacelab. However, payloads configured and integrated into one location are generally incompatible with the other location or require a great deal of

reconfiguration in order to re-fly in alternate locations. The USEC is being designed specifically with these concerns in mind.

Specific design objectives for the USEC are to develop a rectangular, hermetically sealed compartment that will provide adequate containment of hazardous materials and be compatible in multiple locations of the Orbiter (Spacelab, Middeck, and SPACEHAB). NASA Safety Regulations require that hazardous materials be placed inside three levels of containment or be placed in a pressure vessel. The USEC will be qualified as a pressure vessel. This qualification will lift a major part of the burden of meeting NASA's safety requirements from the experimenter, simplifying his experiment design process, as well as his physical and analytical integration, and documentation process.



**SPACELAB RACK**

**MIDDECK/SPACEHAB**

**Figure 5. USEC Spacelab and Middeck/SPACEHAB Configuration**

The planned capabilities of the USEC are to provide approximately 3.3 cubic feet of volume to the experiment. Inside dimensions of the USEC are 18.3" in height, 17.4" in width and 20" in depth. The experiment hardware is to be mounted on flat plates which are held in place by guide rails inside the container, either horizontally or vertically. The USEC will accommodate approximately 110 pounds of experiment mass in the Spacelab configuration and approximately 70 pounds in the Middeck configuration. The USEC is being built to contain a maximum on-orbit design working pressure of 5 psi. Utilities will be provided to the experiment through rear plate connections in Spacelab and front connections in the Middeck. On-orbit change-out of samples will be accomplished through the front access door configured with quick closure captive fasteners.

The huge potential increase in payload activity associated



with the Space station poses the need for extensive on-orbit servicing and change-out of payloads. This means that check-out and safety measures must be built into the systems concepts for payload integration and operation. Figure 6 depicts the Improved Experiment Apparatus Container (IEAC) concept that will provide three levels of containment for safety and capability to leak test newly installed payloads.

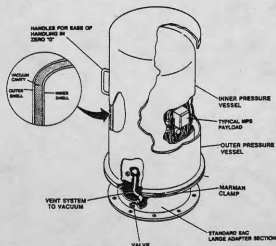


Figure 6. Improved Experiment Apparatus Container

Note that the double wall container plus the vacuum vent provides levels of containment. The initial level of containment can be leak tested by checking for leaks through the vacuum vent.

Figure 7 depicts the scenario for the on-orbit operations of the Space Station Payload Adaptation System onboard the Space Station. Pressurized small payloads and samples will be brought to the Station in the logistic modules. Once on-orbit, the QIB is rotated to its forward position for easy access to payloads for sample exchange and payload change-out. Payloads and samples removed from the QIB are returned to the logistic modules for return to Earth.

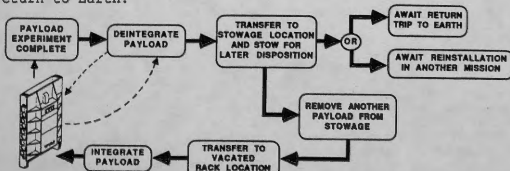


Figure 7. On-orbit Operations Scenario

## Development Plans

The development plan for the preliminary design of the Space Station Payload Adaptation System is illustrated in figure 8. This figure illustrates the interrelationships between required tasks and the subtasks associated with each major task. This effort involves concept design and analysis, the development and testing of engineering mockup, preliminary design of a flight unit followed by the formulation of programmatic plans for the detailed design phase. Specific drivers that will have an impact on design requirements development in Task 1.0 include potential user requirements, Space Station interface definition and operational constraints, the QIB philosophy and QIB program objectives, Shuttle operational constraints and NASA safety considerations.

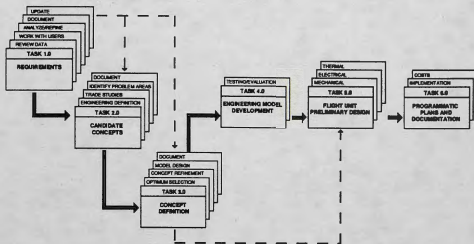


Figure 8. SSPAS Development

Task 2.0 will yield numerous potential candidate concepts that satisfy the design requirements while Task 3.0 will result in the selection of the optimum concept. The selection of the optimum concept will be based upon engineering trades and analyses that compare each concept utilizing selection criteria such as payload mass capability, volume, power, weight, cost, risk and operation simplicity.

In Task 4.0, a full scale engineering mockup will be designed and fabricated that closely replicates the form, fit and physical function of the actual flight unit. The engineering mockup will be used to perform evaluation studies that require a three dimensional projection. The following are planned areas of evaluation for the engineering mockup: 1) evaluate and decide among alternative equipment configurations; 2) determine work space difficulties by simulating operational tasks such as experiment removal and sample change-out; 3) Discover problems of accessibility by simulating maintenance operations; 4) plan the optimum location and routing of wire harnesses, cabling, piping and the location of junction and terminal boxes, connectors, etc.; and 5) demonstrate a proposed or accepted configuration.

Task 5.0 involves the preliminary design of the flight unit. Using the results of the preliminary design effort, implementation plans and cost estimates for all follow-on activities will be formulated in Task 6.0. The implementation plans will cover all elements associated with the Flight Test Phase (C/D) of hardware development. Areas to be addressed include project management, systems engineering and integration, design and development, manufacturing, verification, ground processing and launch and mission operations.

#### **Conclusion**

The Space Station era will provide easier access to space for research, development and exploitation (RD&E) activities for the benefit of mankind. In space as on Earth, RD&E will require equipment to perform the work, energy to operate the equipment and time to do the work. In basic engineering terms these resources can be stated as mass (lb), power (kw) and time (days) in orbit. Currently, on a yearly basis assuming an average of six missions per year the Spacelab will provide approximately  $2.9E6$  (lb)(day)(kw) to support RD&E activities, whereas the Space Station US Laboratory alone will provide approximately  $2.9E8$  (lb)(day)(kw). To fully utilize this two order of magnitude increase in capability to perform space based RT&E, we must apply a systems approach to increasing the efficiency and productivity of microgravity experimentation operations. To accomplish this the Space Station will require a small payload carrier that can adapt Shuttle payloads to the Space Station and allow experiments to take full advantages of the Space Station capabilities such as longer microgravity periods, increased crew availability, and increased resources such as power, data, and heat rejection.

The Space Station Payload Adaptation System presented in this paper will fully exploit the advantages offered by Space Station operations. This rack mounting concept and associated improved experiment containers will allow experiment and sample change-out, payload reconfiguration, and maintenance and refurbishment activities that are consistent with on-orbit safety and operations requirements. Finally, the adapter accomplishes a standardization of interfaces making space easily accessible from both a cost and schedule standpoint.

#### **Reference**

1. National Aeronautics and Space Administration. Space Station "Quick is Beautiful" Research Study Group Final Report, April 1988.